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(21) International Application Number:	PCT/JP96/01641		(74) Agents: ARUGA, Mitsuyuki et al.; Kyodo Building, 3-6, Nihonbashiningyocho 1-chome, Chuo-ku, Tokyo 103 (JP).
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(71) Applicant (for all designated States except US): KAO CORPORATION [JP/JP]; 14-10, Nihonbashi-kayabacho 1-chome, Chuo-ku, Tokyo 103 (JP).			(81) Designated States: CN, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
(72) Inventors; and (75) Inventors/Applicants (for US only): HATADA, Yuji [JP/JP]; Kao Corporation, Research Laboratories, 2606, Akabane, Ichikai-machi, Haga-gun, Tochigi 321-34 (JP). OZAKI, Katsuya [JP/JP]; Kao Corporation, Research Laboratories, 2606, Akabane, Ichikai-machi, Haga-gun, Tochigi 321-34 (JP). ARA, Katsutoshi [JP/JP]; Kao Corporation, Research Laboratories, 2606, Akabane, Ichikai-machi, Haga-gun, Tochigi 321-34 (JP). KAWAI, Shuji [JP/JP]; Kao Corporation, Research Laboratories, 2606, Akabane, Ichikai-machi, Haga-gun, Tochigi 321-34 (JP). ITO, Susumu [JP/JP]; Kao Corporation, Research Laboratories, 2606, Akabane, Ichikai-machi, Haga-gun, Tochigi 321-34 (JP).			Published <i>With international search report.</i> <i>With amended claims.</i>

(54) Title: GENE ENCODING ALKALINE LIQUEFYING ALPHA-AMYLASE

(57) Abstract

The present invention provides a DNA fragment encoding alkaline liquefying α -amylase, recombinant DNA containing the DNA fragment, a transformed microorganism harboring the recombinant DNA, as well as a method for producing alkaline liquefying α -amylase using the transformant. The method of the present invention enables mass production of alkaline liquefying α -amylase useful as a detergent component.

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Description

Gene Encoding Alkaline Liquefying Alpha-Amylase

Technical Field:

The present invention relates to the gene encoding alkaline liquefying α -amylase and fragments thereof, and to recombinant DNA and a transformant bearing the gene or fragments of the gene.

Background Art:

Alpha-amylase has long been used in a variety of fields. For example, it has been used for the saccharification of grains and potatoes in the fermentation industry, as starch paste removers in the textile industry, as digestives in the pharmaceutical industry, and for the manufacture of thick malt syrups in the food industry. Alpha-amylase is an enzyme which acts on a starch-related polysaccharides such as amylose and amylopectin, hydrolyzing solely the α -1,4-glucoside bond of the polysaccharide molecule. Since 1833, when Payen and Persoz first discovered the enzyme, crystalline samples or electrophoretically homogeneous samples of α -amylase have been obtained from a number of different sources including bacteria, fungi, plant seeds, and animal digestive glands.

The present inventors have recently discovered that the efficacy of dish-washing detergents and laundry detergents for clothes can be greatly improved, particularly on starch

dirts, when α -amylase and a debranching enzyme are both incorporated into these detergents (Japanese Patent Application Laid-open (*kokai*) No. 2-132192). However, most of the α -amylases previously found in the natural world exhibit maximal and stable enzymatic activities in the neutral to acidic pH ranges, but scarcely work in an alkaline solution of pH 9-10. There exist only a small number of amylase enzymes that are known to exhibit maximal activities in the alkaline pH range (so-called alkaline α -amylases and alkali-resistant α -amylases). These alkaline α -amylases and alkali-resistant α -amylase include, an enzyme produced by *Bacillus* sp. A-40-2 [Horikoshi, K. et al., *Agric. Biol. Chem.*, 35, 1783 (1971)], an enzyme produced by *Bacillus* sp. NRRL B-3881 [Boyer, E., *J. Bacteriol.*, 110, 992 (1972)], an enzyme produced by *Streptomyces* sp. KSM-9 (Japanese Patent Application Laid-Open (*kokai*) No. 61-209528, an enzyme produced by *Bacillus* sp. H-167 (Japanese Patent Application Laid-Open (*kokai*) No. 62-208278, an enzyme produced by *Bacillus alkalothermophilus* A3-8 (Japanese Patent Application Laid-Open (*kokai*) No. 2-49584, and an enzyme produced by *Natronococcus* sp. Ah-36 (Japanese Patent Application Laid-Open (*kokai*) No. 4-211369.

As used herein, the term "alkaline α -amylase" refers to α -amylases whose optimum pHs fall within the alkaline pH range, whereas the term "alkali-resistant α -amylase" refers to α -amylases which have optimum pHs within the neutral to acidic range but whose activities in the alkaline range are comparable with those obtained at an optimum pH, and in

addition, which retain their stabilities in the alkaline range. By the term "neutral range" is meant the range of pH not less than 6 and less than 8, and the term "alkaline" denotes a pH which is higher than the "neutral range".

Most of these alkaline α -amylases and alkali-resistant amylases are so-called saccharifying α -amylases which decompose starch or starch-related polysaccharides to glucose, maltose, or maltotriose. As such, these enzymes cause problems if they are used as enzymes for detergents, though they are advantageously used in the manufacture of sugar. Thus, there remains a need for so-called alkaline liquefying α -amylases which exhibit resistance against surfactants used in detergents, and which decompose starch or starch-related polysaccharides in a highly random manner. The present inventors continued an extensive search for microorganisms producing an alkaline liquefying α -amylase suitable as a detergent component, and they discovered that an alkalophilic *Bacillus* sp. KSM-AP1378 strain, having its optimum pH for growth in the alkaline range, produces an enzyme exhibiting the activity of an alkaline liquefying α -amylase. They elucidated that this enzyme is useful as an additive in detergent compositions for washing dishes and kitchen utensils and for detergent compositions for clothes (WO94/26881).

Amounts of the enzyme produced may be effectively increased by improving a method for culturing an alkaline liquefying α -amylase-producing microorganism, *Bacillus* sp. KSM-AP1378, or by exploiting mutation. However, in order to

produce the enzyme advantageously on an industrial scale, another approach must be taken.

Amounts of an enzyme produced can be enhanced using a genetic engineering approach, and in addition, the catalytic properties of the enzyme can be improved, using a protein engineering approach, by altering the gene encoding the enzyme. However, the gene encoding an alkaline liquefying α -amylase has not yet been obtained.

Accordingly, an object of the present invention is to provide the gene encoding alkaline liquefying α -amylase and fragments thereof, a transformant harboring recombinant DNA comprising the gene, and a method for producing an alkaline liquefying α -amylase using the transformant.

The DNA encoding the alkaline liquefying α -amylase gene may be further used to produce probes to be used in the isolation of additional, homologous alkaline liquefying α -amylase genes from other microorganisms. Thus, an additional object of the present invention is to provide a means of screening for and isolating additional alkaline liquefying α -amylase enzymes.

Disclosure of the Invention

The present inventors attempted to isolate, from the chromosomal DNA of an alkalophilic *Bacillus* strain, a DNA fragment containing the gene encoding an alkaline liquefying α -amylase, and as a result, they were successful in isolating an approximately 1.8 kb DNA fragment encoding an alkaline liquefying α -amylase. When they transformed a host microorganism using this DNA fragment ligated to a

suitable vector, it was confirmed that the resultant recombinant microorganism produced an alkaline liquefying α -amylase. Moreover, it was found that the amino acid sequence of the alkaline liquefying α -amylase to be encoded is different from that of previously known amylases. The present invention was accomplished based on this finding.

Accordingly, the present invention provides a DNA fragment encoding an alkaline liquefying α -amylase.

The present invention also provides a recombinant DNA comprising the above-described DNA fragment encoding an alkaline liquefying α -amylase.

The present invention also provides a transformed microorganism harboring the above-described recombinant DNA comprising a DNA fragment encoding an alkaline liquefying α -amylase.

The present invention further provides a method for producing an alkaline liquefying α -amylase, by culturing the above-described transformed microorganism and collecting the enzyme.

Brief Description of the Drawings

Fig. 1 shows a restriction enzyme map of a fragment of the gene encoding an alkaline liquefying amylase;

Fig. 2 is a chart depicting construction of pAML100 using a fragment of the gene encoding an alkaline liquefying amylase;

Fig. 3 shows nucleotide sequences of primers used.

Fig. 4 is a pH profile of an alkaline liquefying α -amylase produced by *Bacillus* sp. KSM-AP1378.

Best Mode for Carrying Out the Invention

In the present invention, a useful microorganism which serves as an alkaline liquefying α -amylase gene donor may be, for example, *Bacillus* sp. KSM-AP1378 (FERM BP-3048, deposited July 24, 1989 in Fermentation Research Institute, Agency of Industrial Science and Technology of 1-3, Higashi 1-chome, Tsukuba-shi, Ibaraki, 305 Japan), which is an alkalophilic *Bacillus* strain. This strain was isolated from the soil in the vicinity of the city of Tochigi in Tochigi Prefecture, Japan by the present inventors and identified as a strain which produces significant amounts of alkaline liquefying α -amylase. This strain was deposited at the Fermentation Research Institute, Agency of Industrial Science and Technology (1-3, Higashi 1-chome, Tsukuba-shi, Ibaraki-ken, 305, Japan) under FERM BP-3048 on August 8, 1990 (originally deposited as P-10886 on July 24, 1989).

In order to obtain chromosomal DNA from a donor microorganism, the method proposed by Marmur, J. (J. Mol. Biol., 3, 208 (1961)) or the method proposed by Saito, H. and Miura, K. (Biochem. Biophys. Acta, 72, 619 (1963)) may be used. Other similar methods may also be used.

DNA fragments comprising the alkaline liquefying α -amylase gene are prepared by cleaving the thus-obtained chromosomal DNA using restriction enzymes. Restriction enzymes which may be used are not particularly

limited so long as they do not fragment the gene. The alkaline liquefying α -amylase gene may also be obtained by PCR (Mullis, K.B. and Faloona, F.A., Methods Enzymol., 155, 335 (1987); Saiki, R. K. et al., Science, 239, 487 (1988). For example, the gene may be obtained through the synthesis of primers having sequences corresponding to those on the upstream side of the 5'-terminus and on the downstream side of the 3'-terminus of the essential region based on the nucleotide sequence described in Sequence No. 2, and subsequently conducting PCR using, the chromosomal DNA of an alkaline liquefying α -amylase-producing microorganism as a template. Alternatively, an intact gene may be obtained by first obtaining a fragment of the alkaline liquefying α -amylase gene from an alkaline liquefying α -amylase-producing microorganism using any procedure, followed by PCR which amplifies the upstream and downstream sides of the fragmentary gene.

The thus-prepared genetic fragment is then subjected to cloning. Host/vector systems which may be used are not particularly limited, so far as that host bacterial strains express the alkaline liquefying α -amylase gene of the present invention, that the recombinant DNA molecules can be replicated in the host bacteria, and that the integrated gene can be stably harbored. For example, members of the EK system in which the host is *E. coli* K-12, and members of the BS system in which the host is *Bacillus subtilis* Marburg, may be used. Use of the EK system, which

encompasses many kinds of vectors and which is extensively studied genetically, provides good results and thus is preferred. Specific examples of host bacteria include HB101, C600, and JM109 of the EK system, and BD170, MI112, and ISW1214 of the BS system. Specific examples of vectors include pBR322 and pUC18 for the EK system, and pUB110 and pHY300PLK for the BS system.

A recombinant plasmid DNA molecule is created by cleaving a vector with a restriction enzyme followed by ligation with the above-mentioned chromosomal or PCR-amplified DNA fragment. The ligation may be achieved, for example, through the use of a DNA ligase.

Methods for transforming host bacterial strains using a recombinant DNA molecule are not particularly limited. For example, a calcium chloride method (Mandel, M. and Higa, A., J. Mol. Biol., 53, 159 (1970)) may be used in the case of hosts of the EK system, and a protoplast method (Chang, C. and Cohen, S.N., Mol. Gen. Genet., 168, 111 (1978)) may be used in the case of hosts of the BS system. Selection of recombinant microorganisms are performed as follows. First, microorganisms which have been transformed with DNA which contains a vector-derived DNA fragment are selected, using as an index a character which is not inactivated by insertion of exogenous chromosomal DNA fragments, such as resistance to antibiotics coded onto the vector DNA. For example, in a specific case in which pBR322 of the EK system is used as a vector, and a *Hind*III fragment of chromosomal DNA is inserted into the *Hind*III cleavage

site of pBR322, the tetracycline resistant gene is inactivated, so a primary selection may be conducted by growth of the transformants that confer ampicillin resistance without having a *Hind*III cleavage site in the ampicillin gene. Subsequently, the selected transformants are transferred onto agar plates containing starch, using, for example, a replica method, and are then cultured so as to form colonies. By staining the starch contained in the starch-containing agar plates using an iodine-containing solution, target recombinant microorganisms can be selected as they decompose starch around the colonies.

The recombinant DNA molecule harbored by the thus-obtained recombinant microorganism can be extracted using standard procedures for preparing plasmids or phage DNAs (Maniatis, T. et al., Molecular Cloning, Cold Spring Harbor Laboratory, New York (1982)). When cleavage patterns obtained through the use of various restriction enzymes are analyzed by electrophoresis, it is confirmed that the recombinant DNA molecule is a ligated product of the vector DNA molecule and a DNA fragment containing the alkaline liquefying α -amylase gene.

The gene encoding an alkaline liquefying α -amylase is contained in a DNA fragment of about 2.1 kb shown in the restriction enzyme map of Fig. 1, and is present in the segment of about 1.6 kb shown by the white bar. The gene has a nucleotide sequence shown as Sequence No. 2. In this sequence, the 5' terminus and 3' terminus correspond to the left-hand side and the right-hand side, respectively, of

the fragment of about 2.1 kb shown as Sequence 2. In this sequence is observed an open reading frame (ORF) starting at the 145th nucleotide, ATG, and coding for a sequence consisting of 516 amino acid residues described in Sequence No. 1. Thirteen bases (13 b) upstream of the ORF, there exists a sequence AAGGAG which is highly complementary to the 3' terminal sequence of the 16S ribosomal RNA of *Bacillus subtilis* (McLaughlin, J.R. et al., J. Biol. Chem., 256, 11283 (1981)). On a further upstream region extending nucleotides from 9 to 36, there exists a sequence TTGAAA 16b TATGGT which has high homology with the consensus sequence of a σ^A -type promoter (Gitt, M.A. et al, J. Biol. Chem., 260, 7178 (1985)). Similarly, another σ^A -type promoter sequence is found at nucleotides from 95 to 125. The amino acid sequence of the 10 amino acid residues on the amino terminus side in an alkaline liquefying α -amylase purified from a culture of *Bacillus* sp. KSM-AP1378 coincides with the sequence extending from the 37th amino acid (amino acid Nos. 37-46 in Sequence No. 2) deduced from the nucleotide sequence of the present DNA fragment.

When the nucleotide sequence of the gene of the present invention and a deduced amino acid sequence were compared with those of α -amylase known hitherto, it was confirmed that the present gene includes a novel nucleotide sequenced, with the deduced amino acid sequence encoded by the gene being different from those of other α -amylases such as a liquefying α -amylase produced by *Bacillus amylolique* (Takkinen, K. et al., J. Biol. Chem., 258, 1007 (1983)), a liquefying α -amylase

produced by *Bacillus stearothermophilus* (Nakajima, R. et al., J. Bacteriol., 163, 401 (1985)), a liquefying α -amylase produced by *Bacillus licheniformis* (Yuuki, T et al., J. Biochem., 98, 1147 (1985)), or a liquefying α -amylase produced by *Bacillus* sp. 707 (Tsukamoto, A. et al., Biochem. Biophys. Res. Commun., 151, 25 (1988)).

An example of a preferred recombinant DNA molecule containing the entire region of the alkaline liquefying α -amylase gene is plasmid pAML100 (Fig. 2). This recombinant plasmid has a size of 4.4 kb and formed of a fragment containing a 1.8 kb fragment which contains the alkaline liquefying α -amylase gene and pUC19. An example of a preferred recombinant microorganism harboring the recombinant DNA molecule is an *E. coli* HB101(pAML100) strain. This strain was obtained by transforming *E. coli* HB101 strain with the recombinant plasmid pAML100 using a standard transformation method. When this strain is cultured using a medium routinely employed for culturing *E. coli*, it produces an alkaline liquefying α -amylase. The optimum reaction pH of the thus-produced enzyme is pH 8-9. This agrees well with the activity-pH relationship profile determined for the alkaline liquefying α -amylase produced by the gene donor bacterial strain, *Bacillus* sp. KSM-AP1378 (Fig. 4).

The DNA fragments of the present invention are not necessarily limited only to those encoding the amino acid sequences shown in the below-described sequence listing, so far as they encode a protein exhibiting the enzymatic activity of interest, and they encompass DNA fragments

encoding an amino acid sequence in which one or more amino acids are substituted, added, deleted, inverted, or inserted. An example of such DNA is one encoding an amino acid sequence equivalent to the amino acid sequence described in Sequence No. 1 from which up to 32 amino acids on the N-terminal side have been deleted.

In order to produce an alkaline liquefying α -amylase using the transformed microorganism of the present invention, a transformed microorganism harboring the aforementioned DNA fragment of the present invention is subjected to culturing. Alternatively, the DNA fragment may be integrated in a variety of expression vectors to obtain transformed microorganisms with enhanced expression ability, followed by culturing of the resultant transformants. Moreover, the transformed microorganisms may be cultured under different conditions depending on the identity of the microorganisms. Thus, culture conditions suited for the host may be used. In order to collect an alkaline liquefying α -amylase from the resultant culture, a routine method (such as the method described in WO94/26881) may be used.

The DNA fragments of the present invention may be further used as probes for the isolation of homologous alkaline liquefying α -amylase genes from other organisms.

Examples

The present invention will next be described in more detail by way of examples, which should not be construed as limiting the invention thereto. Concentrations in the

Examples are all on a basis of % by weight.

Example 1:

Bacillus sp. KSM-AP1378 producing an alkaline liquefying α -amylase was inoculated in 5 ml of medium A (Table 1) and subjected to shaking culture at 30°C for 24 hours.

One ml of the culture was inoculated in 100 ml of the same medium, followed by shaking culture at 30°C for a further 12 hours. Subsequently, cells were collected by centrifugation and about 1 mg of chromosomal DNA was obtained in accordance with a method proposed by Saito and Miura (Saito, H. and Miura K., Biochim Biophys. Acta, 72, 619 (1963)).

Table 1

Composition of medium A

Soluble starch	1.0%
Polypepton	1.0%
Yeast extract	0.5%
KH ₂ PO ₄	0.1%
Na ₂ HPO ₄ · 12H ₂ O	0.25%
MgSO ₄ · 7H ₂ O	0.02%
CaCl ₂ · 2H ₂ O	0.02%
FeSO ₄ · 7H ₂ O	0.001%
MnCl ₂ · 4H ₂ O	0.0001%
Na ₂ CO ₃	1.0% (separately sterilized)

Example 2:

It is known that many members of the amylase family

possess I-IV regions where amino acid sequences are conserved at a high level (Nakajima, R. et al., Appl. Microbiol. Biotechnol., 23, 355 (1986)). Therefore, primers 1 and 2 (Figs. 1 and 3) corresponding to regions II and IV were synthesized based on the amino acid sequence of region II and the amino acid sequence of region IV, which are particularly conserved regions among regions I through IV of known alkaline liquefying α -amylases. Using the thus-synthesized primers and chromosomal DNA of KSM-AP1378 (which served as template), PCR was conducted (one cycle = 94°C x 1 min. + 42°C x 1 min. + 60°C x 2 min., 30 cycles). A gene fragment of approximately 0.3 kb (fragment A) shown in Fig. 1 was obtained, and the nucleotide sequence of this fragment was determined. As a result, it was found that the present fragment was coded with an amino acid sequence exhibiting a non-negligible level of homology with the amino acid sequence extending from region II through region IV of known liquefying amylase.

Example 3:

Using fragment A as a probe, chromosomal DNA of XbaI-digested KSM-AP1378 was subjected to Southern hybridization. As a result, it was confirmed that there was a band which hybridized at the location of approximately 1.0 kb. An amplified fragment of approximately 0.7 kb (fragment B) was obtained by an inverse PCR method (Triglia, T. et al., Nucleic Acids Res., 16, 81 (1988)) using primers synthesized from the terminal sequences of fragment A (on the

side of region II: primer 3; on the side of region IV: primer 4) and DNAs which had been obtained by intramolecularly ligating *Xba*I-digested KSM-AP1378 chromosomal DNA (Fig. 1) as template. The nucleotide sequence of fragment B was determined, which revealed that the present fragment contained a stretch, approximately 0.6 kb region downstream from region IV. The present fragment contained a termination codon for the ORF, which was deduced to be attributed to alkaline liquefying α -amylase.

Example 4:

A primer was designed and synthesized based on the N-terminal amino acid sequence (7 amino acids) of alkaline liquefying α -amylase from the KSM-AP1378 strain (Fig. 3). Using the resultant primer (primer 5) in combination with the aforementioned primer 3 (Fig. 3) and, as a template, chromosomal DNA of KSM-AP1378, PCR was conducted to obtain a fragment of approximately 0.7 kb (fragment C, Fig. 1), thereby determining its nucleotide sequence.

Example 5:

A primer containing 21 bases, stretching directly downstream of the nucleotide sequence encoding N-terminal amino acid sequence of the purified enzyme, was synthesized (primer 6). Using primers 6 and 7 (Figs. 1 and 3) and DNAs which had been obtained by intramolecularly ligating *Hind*III-digested KSM-AP1378 chromosomal DNA (Fig. 1) as templates,

an inverse PCR method was performed, obtaining a 1.2 kb fragment in which an upstream 0.8 kb fragment (fragment D) and a downstream *PstI-HindIII* 0.4 kb fragment had been ligated at the *HindIII* site. The nucleotide sequence of the fragment D region was determined, which revealed the presence of a signal sequence composed of 31 amino acids, MKLHNRIISVLLTLLAVAVLFPYPMTEPAQA (from No. 1 to No. 31 of Sequence No. 2), a deduced SD sequence composed of AAGGAG (nucleotides 127-132; McLaughlin, J.R. et al., J. Biol. Chem., 260, 7178 (1985)), and two kinds of deduced promoter sequences (-35 sequences, TTGAAA; -10 sequence, TATGGT, and -35 sequence, TTGACT; -10 sequence, TAAATT).

Example 6:

Using primer A located at approximately 0.1 kb upstream of the promoter sequence, primer B located 79 b downstream of the termination codon, and chromosomal DNA of KSM-AP1378 as templates, a stretch of approximately 1.8 kb between the primers was amplified by PCR. The resultant amplified fragment was inserted into the *SmaI* site of pUC19, and then introduced into *E. coli* HB101. The transformant was allowed to grow on an LB agar medium containing 0.4% Starch azure and 15 µg/ml ampicillin. Colonies which had formed transparent halos around them were isolated as an *E. coli* strain that produced liquefying α -amylase. A recombinant plasmid was prepared from this transformant, and a restriction enzyme map of the plasmid was made. In the map, it was confirmed that an approximately 1.8 kb DNA fragment (fragment E) shown in Fig. 1 was contained. This recombinant plasmid was designated plasmid

pAML100 (Fig. 2).

Example 7:

The recombinant *E. coli* obtained in Example 6 was subjected to shaking culture for 12 hours in 5 ml of an LB liquid medium containing 50 µg/ml of ampicillin. One (1) ml of the culture was inoculated to 100 ml of an LB medium (containing ampicillin), followed by shaking culture at 37°C for 24 hours. Cells collected by centrifugal separation were suspended in Tris-HCl buffer (pH 8.0), and were disrupted by sonication. After the cells were sonicated, cell debris was removed by centrifugal separation, and the resultant supernatant was used as a cell-free extract. As a control, the cell-free extract of HB101(PUC19) strain was separately prepared in a similar manner. α -Amylase activities in these extracts were measured by first causing a reaction, at 50°C for 15 minutes, in a reaction mixture containing 50 mM glycine-NaCl-NaOH buffer (pH 10) and soluble starch, and then by quantitatively determining the produced reducing sugar by the 3,5-dinitrosalicylic acid method (WO94/26881). One unit of enzymatic activity was defined as the amount of protein that produced a quantity per minute of reducing sugar equivalent to 1 µmol of glucose. As a result, α -amylase activity was detected in the cell-free extract of strain HB101(pAML100). The optimum working pH of α -amylase was found to fall within the pH range between 8 and 9. This result coincides well with the optimum pH of liquefying α -amylase produced by *Bacillus* sp. KSM-API378

(Fig. 4). For the measurement of enzymatic activities, the buffers shown in Table 2 below were used (each at 40 mM).

Table 2

pH 3.5-5.5: Acetate buffer
pH 5.5-8.5: Tris-maleic acid buffer
pH 8.5-10.5: Glycine-NaCl-NaOH buffer
pH 10.5-11.0: Na₂CO₃-NaHCO₃ buffer

Industrial Applicability:

According to the present invention, it is possible to obtain a gene encoding for alkaline liquefying α -amylase exhibiting the maximum activity in the alkaline pH range as well as a microorganism harboring such gene. Use of them facilitates mass production of alkaline liquefying α -amylase.

Sequence Listing

Information for Sequence No. 1:

(i) Sequence Characteristics:

- (A) Length: 516 amino acids
- (B) Type: amino acid
- (D) Topology: linear

(ii) Molecule Type: peptide

(xi) Sequence Description: Sequence No. 1:

Met Lys Leu His Asn Arg Ile Ile Ser Val Leu Leu Thr Leu Leu Leu
1 5 10 15

Ala Val Ala Val Leu Phe Pro Tyr Met Thr Glu Pro Ala Gln Ala His
20 25 30

His Asn Gly Thr Asn Gly Thr Met Met Gln Tyr Phe Glu Trp His Leu
35 40 45

Pro Asn Asp Gly Asn His Trp Asn Arg Leu Arg Asp Asp Ala Ala Asn
50 55 60

Leu Lys Ser Lys Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Trp Lys
65 70 75 80

Gly Thr Ser Gln Asn Asp Val Gly Tyr Gly Ala Tyr Asp Leu Tyr Asp
85 90 95

Leu Gly Glu Phe Asn Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr
100 105 110

Arg Ser Gln Leu Gln Gly Ala Val Thr Ser Leu Lys Asn Asn Gly Ile
115 120 125

Gln Val Tyr Gly Asp Val Val Met Asn His Lys Gly Gly Ala Asp Gly
130 135 140

Thr Glu Met Val Asn Ala Val Glu Val Asn Arg Ser Asn Arg Asn Gln
145 150 155 160

Glu Ile Ser Gly Glu Tyr Thr Ile Glu Ala Trp Thr Lys Phe Asp Phe
 165 170 175
 Pro Gly Arg Gly Asn Thr His Ser Asn Phe Lys Trp Arg Trp Tyr His
 180 185 190
 Phe Asp Gly Thr Asp Trp Asp Gln Ser Arg Gln Leu Gln Asn Lys Ile
 195 200 205
 Tyr Lys Phe Arg Gly Thr Gly Lys Ala Trp Asp Trp Glu Val Asp Ile
 210 215 220
 Glu Asn Gly Asn Tyr Asp Tyr Leu Met Tyr Ala Asp Ile Asp Met Asp
 225 230 235 240
 His Pro Glu Val Ile Asn Glu Leu Arg Asn Trp Gly Val Trp Tyr Thr
 245 250 255
 Asn Thr Leu Asn Leu Asp Gly Phe Arg Ile Asp Ala Val Lys His Ile
 260 265 270
 Lys Tyr Ser Tyr Thr Arg Asp Trp Leu Thr His Val Arg Asn Thr Thr
 275 280 285
 Gly Lys Pro Met Phe Ala Val Ala Glu Phe Trp Lys Asn Asp Leu Ala
 290 295 300
 Ala Ile Glu Asn Tyr Leu Asn Lys Thr Ser Trp Asn His Ser Val Phe
 305 310 315 320
 Asp Val Pro Leu His Tyr Asn Leu Tyr Asn Ala Ser Asn Ser Gly Gly
 325 330 335
 Tyr Phe Asp Met Arg Asn Ile Leu Asn Gly Ser Val Val Gln Lys His
 340 345 350
 Pro Ile His Ala Val Thr Phe Val Asp Asn His Asp Ser Gln Pro Gly
 355 360 365
 Glu Ala Leu Glu Ser Phe Val Gln Ser Trp Phe Lys Pro Leu Ala Tyr
 370 375 380

Ala Leu Ile Leu Thr Arg Glu Gln Gly Tyr Pro Ser Val Phe Tyr Gly
385 390 395 400
Asp Tyr Tyr Gly Ile Pro Thr His Gly Val Pro Ser Met Lys Ser Lys
405 410 415
Ile Asp Pro Leu Leu Gln Ala Arg Gln Thr Tyr Ala Tyr Gly Thr Gln
420 425 430
His Asp Tyr Phe Asp His His Asp Ile Ile Gly Trp Thr Arg Glu Gly
435 440 445
Asp Ser Ser His Pro Asn Ser Gly Leu Ala Thr Ile Met Ser Asp Gly
450 455 460
Pro Gly Gly Asn Lys Trp Met Tyr Val Gly Lys His Lys Ala Gln
465 470 475 480
Val Trp Arg Asp Ile Thr Gly Asn Arg Ser Gly Thr Val Thr Ile Asn
485 490 495
Ala Asp Gly Trp Gly Asn Phe Thr Val Asn Gly Gly Ala Val Ser Val
500 505 510
Trp Val Lys Gln
516

Information for Sequence No. 2:

(i) Sequence Characteristics:

- (A) Length: 1776 base pairs
- (B) Type: nucleic acid
- (C) Strandedness: double
- (D) Topology: linear

(ii) Molecule Type: DNA (genomic)

(vi) Original Source:

- (A) Organism: *Bacillus* sp.

(B) Strain: KSM-AP1378

(xi) Sequence Description: Sequence No. 2:

ATATAAATTGAAATGAACA CCTATGAAAA TATGGTAGCG ATTGCACGAC GAGAAAAC	60
TTGGGACTTA GGAAGTGATA TTAAAGGATT TTTTTGACT TGTGTGAAA ACGCTTGCAT	120
AAATTGAAGG AGAGGGTGCT TTTT ATG AAA CTT CAT AAC CGT ATA ATT AGC GTA	174
Met Lys Leu His Asn Arg Ile Ile Ser Val	
1	5
CTA TTA ACA CTA TTG TTA GCT GTA GCT GTT TTG TTT CCA TAT ATG ACG	222
Leu Leu Thr Leu Leu Ala Val Ala Val Leu Phe Pro Tyr Met Thr	
15	20
GAA CCA GCA CAA GCC CAT CAT AAT GGG ACG AAT GGG ACC ATG ATG CAG	270
Glu Pro Ala Gln Ala His His Asn Gly Thr Asn Gly Thr Met Met Gln	
30	35
TAT TTT GAA TGG CAT TTG CCA AAT GAC GGG AAC CAC TGG AAC AGG TTA	318
Tyr Phe Glu Trp His Leu Pro Asn Asp Gly Asn His Trp Asn Arg Leu	
45	50
CGA GAT GAC GCA GCT AAC TTA AAG AGT AAA GGG ATT ACC GCT GTT TGG	366
Arg Asp Asp Ala Ala Asn Leu Lys Ser Lys Gly Ile Thr Ala Val Trp	
60	65
ATT CCT CCT GCA TGG AAG GGG ACT TCG CAA AAT GAT GTT GGG TAT GGT	414
Ile Pro Pro Ala Trp Lys Gly Thr Ser Gln Asn Asp Val Gly Tyr Gly	
75	80
GCC TAT GAT TTG TAC GAT CTT GGT GAG TTT AAC CAA AAG GGA ACC GTC	462
Ala Tyr Asp Leu Tyr Asp Leu Gly Glu Phe Asn Gln Lys Gly Thr Val	
95	100
CGT ACA AAA TAT GGC ACA AGG AGT CAG TTG CAA GGT GCC GTG ACA TCT	510

110	115	120	
TTG AAA AAT AAC GGG ATT CAA GTT TAT GGG GAT GTC CTG ATG AAT CAT			558
Leu Lys Asn Asn Gly Ile Gln Val Tyr Gly Asp Val Val Met Asn His			
125	130	135	
AAA GGT GGA GCA GAC GGG ACA GAG ATG GTA AAT GCG GTG GAA GTG AAC			606
Lys Gly Gly Ala Asp Gly Thr Glu Met Val Asn Ala Val Glu Val Asn			
140	145	150	
CGA AGC AAC CGA AAC CAA GAA ATA TCA GGT GAA TAC ACC ATT GAA GCA			654
Arg Ser Asn Arg Asn Gln Glu Ile Ser Gly Glu Tyr Thr Ile Glu Ala			
155	160	165	170
TGG ACG AAA TTT GAT TTC CCT GGA AGA GGA AAT ACC CAT TCC AAC TTT			702
Trp Thr Lys Phe Asp Phe Pro Gly Arg Gly Asn Thr His Ser Asn Phe			
175	180	185	
AAA TGG CGC TGG TAT CAT TTT GAT GGG ACA GAT TGG GAT CAG TCA CGT			750
Lys Trp Arg Trp Tyr His Phe Asp Gly Thr Asp Trp Asp Gln Ser Arg			
190	195	200	
CAG CTT CAG AAC AAA ATA TAT AAA TTC AGA GGT ACC GGA AAG GCA TGG			798
Gln Leu Gln Asn Lys Ile Tyr Lys Phe Arg Gly Thr Gly Lys Ala Trp			
205	210	215	
GAC TGG GAA GTA GAT ATA GAG AAC GGC AAC TAT GAT TAC CTT ATG TAT			846
Asp Trp Glu Val Asp Ile Glu Asn Gly Asn Tyr Asp Tyr Leu Met Tyr			
220	225	230	
GCA GAC ATT GAT ATG GAT CAT CCA GAA GTA ATC AAT GAA CTT AGA AAT			894
Ala Asp Ile Asp Met Asp His Pro Glu Val Ile Asn Glu Leu Arg Asn			
235	240	245	250
TGG GGA GTT TGG TAT ACA AAT ACA CTT AAT CTA GAT GGA TTT AGA ATC			942
Trp Gly Val Trp Tyr Thr Asn Thr Leu Asn Leu Asp Gly Phe Arg Ile			
255	260	265	

GAT GCT GTG AAA CAT ATT AAA TAC AGC TAT ACG AGA GAT TGG CTA ACA 990
 Asp Ala Val Lys His Ile Lys Tyr Ser Tyr Thr Arg Asp Trp Leu Thr
 270 275 280
 CAT GTG CGT AAC ACC ACA GGT AAA CCA ATG TTT GCA GTT GCA GAA TTT 1038
 His Val Arg Asn Thr Thr Gly Lys Pro Met Phe Ala Val Ala Glu Phe
 285 290 295
 TGG AAA AAT GAC CTT GCT GCA ATC GAA AAC TAT TTA AAT AAA ACA AGT 1086
 Trp Lys Asn Asp Leu Ala Ile Glu Asn Tyr Leu Asn Lys Thr Ser
 300 305 310
 TGG AAT CAC TCC GTG TTC GAT GTT CCT CTT CAT TAT AAT TTG TAC AAT 1134
 Trp Asn His Ser Val Phe Asp Val Pro Leu His Tyr Asn Leu Tyr Asn
 315 320 325 330
 GCA TCT AAT AGT GGT GGC TAT TTT GAT ATG AGA AAT ATT TTA AAT GGT 1182
 Ala Ser Asn Ser Gly Gly Tyr Phe Asp Met Arg Asn Ile Leu Asn Gly
 335 340 345
 TCT GTC GTA CAA AAA CAC CCT ATA CAT GCA GTC ACA TTT GTT GAT AAC 1230
 Ser Val Val Gln Lys His Pro Ile His Ala Val Thr Phe Val Asp Asn
 350 355 360
 CAT GAC TCT CAG CCA GGA GAA GCA TTG GAA TCC TTT GTT CAA TCG TGG 1278
 His Asp Ser Gln Pro Gly Glu Ala Leu Glu Ser Phe Val Gln Ser Trp
 365 370 375
 TTC AAA CCA CTG GCA TAT GCA TTG ATT CTG ACA AGG GAG CAA GGT TAC 1326
 Phe Lys Pro Leu Ala Tyr Ala Leu Ile Leu Thr Arg Glu Gln Gly Tyr
 380 385 390
 CCT TCC GTA TTT TAC GGT GAT TAC TAC GGT ATA CCA ACT CAT GGT GTT 1374
 Pro Ser Val Phe Tyr Gly Asp Tyr Tyr Gly Ile Pro Thr His Gly Val
 395 400 405 410
 CCT TCG ATG AAA TCT AAA ATT GAT CCA CTT CTG CAG GCA CGT CAA ACG 1422
 Pro Ser Met Lys Ser Lys Ile Asp Pro Leu Leu Gln Ala Arg Gln Thr

415	420	425	
TAT GCC TAC GGA ACC CAA CAT GAT TAT TTT GAT CAT CAT GAT ATT ATC			1470
Tyr Ala Tyr Gly Thr Gln His Asp Tyr Phe Asp His His Asp Ile Ile			
430	435	440	
GGC TGG ACG AGA GAA GGG GAC AGC TCC CAC CCA AAT TCA GGA CTT GCA			1518
Gly Trp Thr Arg Glu Gly Asp Ser Ser His Pro Asn Ser Gly Leu Ala			
445	450	455	
ACT ATT ATG TCC GAT GGG CCA GGG GGT AAT AAA TGG ATG TAT GTC GGG			1566
Thr Ile Met Ser Asp Gly Pro Gly Gly Asn Lys Trp Met Tyr Val Gly			
460	465	470	
AAA CAT AAA GCT GGC CAA GTA TGG AGA GAT ATC ACC GGA AAT AGG TCT			1614
Lys His Lys Ala Gly Gln Val Trp Arg Asp Ile Thr Gly Asn Arg Ser			
475	480	485	490
GGT ACC GTC ACC ATT AAT GCA GAT GGT TGG GGG AAT TTC ACT GTA AAC			1662
Gly Thr Val Thr Ile Asn Ala Asp Gly Trp Gly Asn Phe Thr Val Asn			
495	500	505	
GGA GGG GCA GTT TCG GTT TGG GTG AAG CAA TAAATAAGGA ACAAGAGGCG			1712
Gly Gly Ala Val Ser Val Trp Val Lys Gln			
510	515		
AAAATTACTT TCCTACATGC AGAGCTTCC GATCACTCAT ACACCCAATA TAAATTGGAA			1772
GCTT			1776

CLAIMS:

1. A DNA molecule encoding alkaline liquefying α -amylase activity.
2. A DNA molecule as defined in Claim 1, which encodes the amino acid sequence described in Sequence No. 1 or a functional fragment thereof.
3. A DNA molecule encoding a protein exhibiting alkaline liquefying α -amylase activity and possessing an amino acid sequence described in Sequence No. 1 in which one or more amino acids are substituted, added, deleted, inverted, or inserted.
4. A DNA molecule as defined in any one of Claims 1 through 3, further comprising a nucleotide sequence for regulating expression of a gene.
5. A recombinant DNA containing the DNA molecule of any one of Claims 1 through 4.
6. A transformed microorganism harboring the recombinant DNA of Claim 5.
7. A method for producing alkaline liquefying α -amylase, comprising culturing the transformed microorganism of Claim 6 and isolating the alkaline liquefying α -amylase produced by the microorganism.
8. A DNA molecule which hybridizes to a DNA sequence which is complementary to the nucleic acid sequence of SEQ ID No. 2.
9. A protein encoded by the DNA molecule of Claim 9.
10. A DNA molecule which hybridizes to a DNA sequence which is complementary to the nucleic acid sequence of SEQ ID No. 2, wherein said DNA molecule encodes a protein having alkaline

liquefying α -amylase activity.

11. A protein encoded by the DNA molecule of Claim 11.
12. The recombinant DNA plasmid pAML100.
13. The recombinant *E. coli* strain HB101(pAML100).

The present invention provides a DNA fragment encoding alkaline liquefying α -amylase, recombinant DNA containing the DNA fragment, a transformed microorganism harboring the recombinant DNA, as well as a method for producing alkaline liquefying α -amylase using the transformant. The method of the present invention enables mass production of alkaline liquefying α -amylase useful as a detergent component.

AMENDED CLAIMS

[received by the International Bureau on 11 December 1996 (11.12.96); original claims 4, 9, 11 amended; remaining claims unchanged (2 pages)]

1. A DNA molecule encoding alkaline liquefying α -amylase activity.
2. A DNA molecule as defined in Claim 1, which encodes the amino acid sequence described in Sequence No. 1 or a functional fragment thereof.
3. A DNA molecule encoding a protein exhibiting alkaline liquefying α -amylase activity and possessing an amino acid sequence described in Sequence No. 1 in which one or more amino acids are substituted, added, deleted, inverted, or inserted.
4. A DNA molecule as defined in any one of Claims 1 through 3, further comprising a nucleotide sequence for regulating expression of a gene.
5. A recombinant DNA containing the DNA molecule of any one of Claims 1 through 4.
6. A transformed microorganism harboring the recombinant DNA of Claim 5.
7. A method for producing alkaline liquefying α -amylase, comprising culturing the transformed microorganism of Claim 6 and isolating the alkaline liquefying α -amylase produced by the microorganism.
8. A DNA molecule which hybridizes to a DNA sequence which is complementary to the nucleic acid sequence of SEQ ID No. 2.
9. A protein encoded by the DNA molecule of Claims 1 through 4.
10. A DNA molecule which hybridizes to a DNA sequence which is complementary to the nucleic acid sequence of SEQ ID No. 2, wherein said DNA molecule encodes a protein having alkaline

liquefying α -amylase activity.

11. A protein encoded by the DNA molecule of Claim 10.
12. The recombinant DNA plasmid pAML100.
13. The recombinant *E. coli* strain HB101(pAML100).

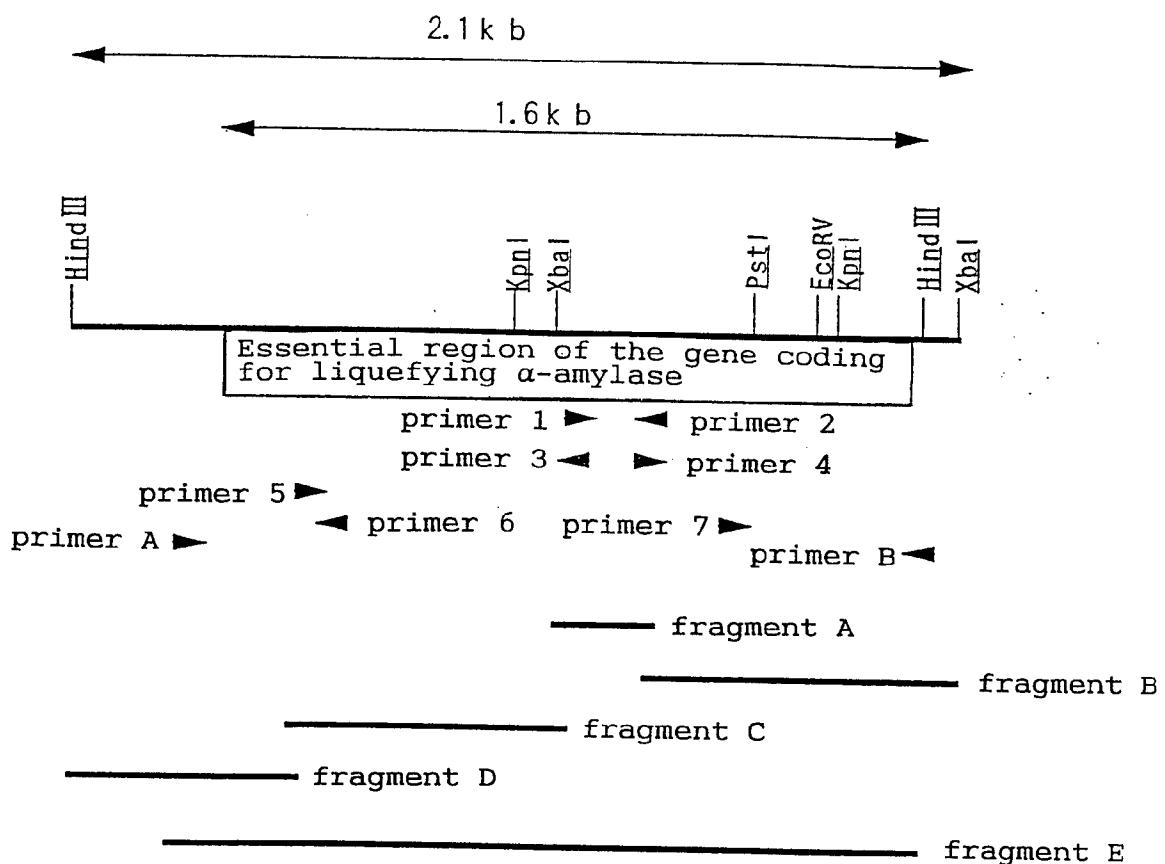


FIG. 1

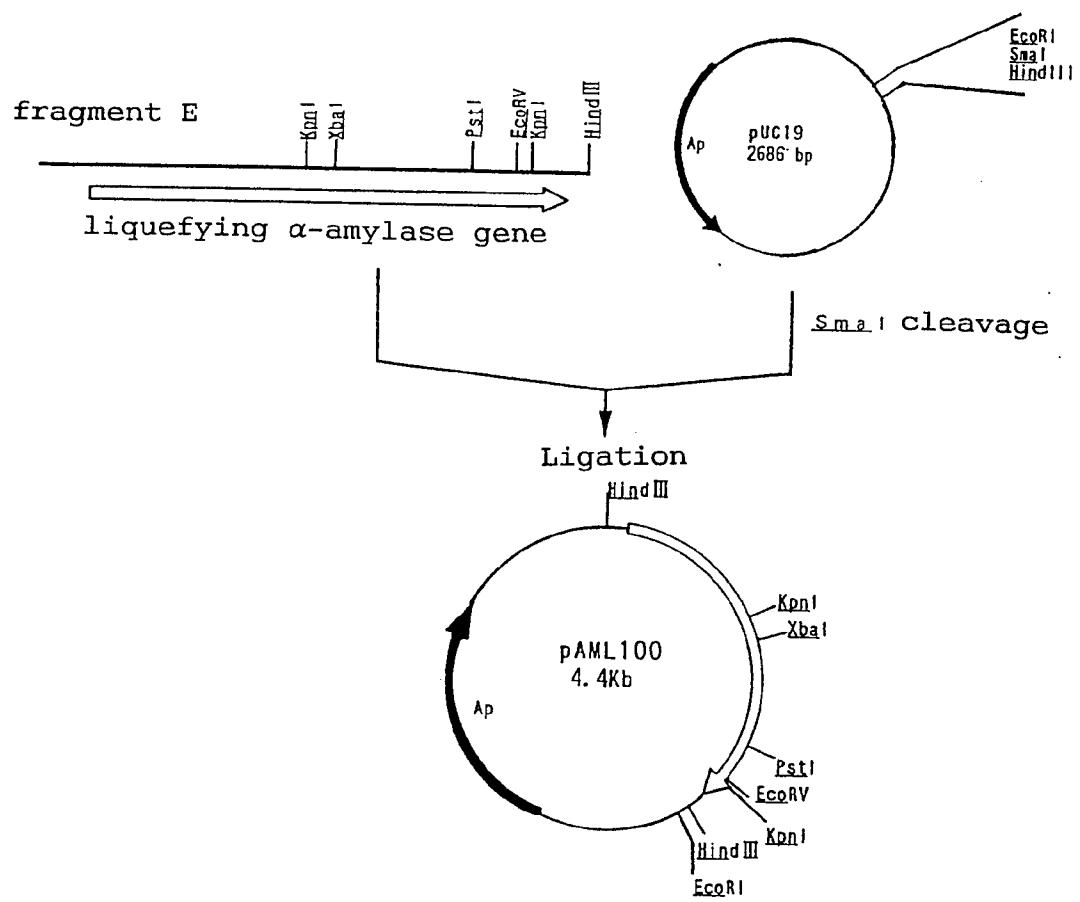


FIG. 2

FIG. 3

primer 1 5' TAGACGCAGTAAAACACATAAA 3'

C T C C G T C
G G G T
T T T

primer 2 3' CGACAATGAAAACAACTATTAGTACT 5'

G G G G G G G
C C C C
T T T T

primer 3 5' AGCCAATCTCTCGTATAGCTGTA 3'

primer 4 5' GTACAAAAACACCCTATACATG 3'

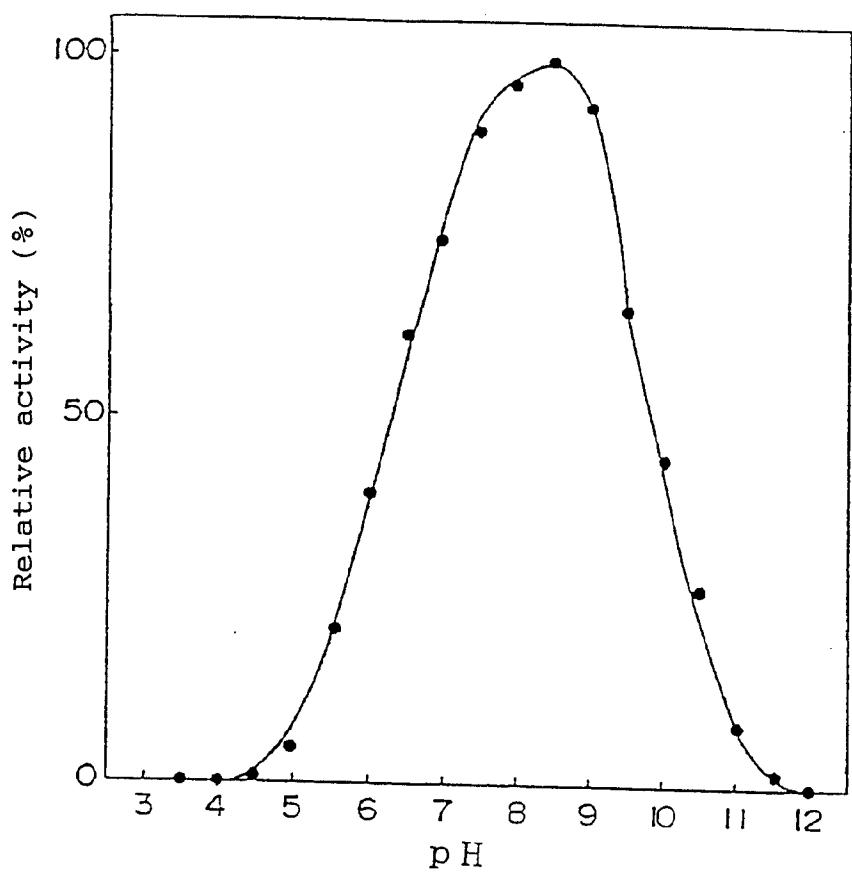
primer 5 5' AATGGAACATGATGCAGTA 3'
T T T

primer 6 5' CATTGGCAAATGCCATTCAA 3'

primer 7 5' AAAATTGATCCACTTCTGCAG 3'

primer A 5' CAGCGCGTATAATATAAATTGAAAT 3'

primer B 5' AAGCTTCCAATTATATTGGGTGTAT 3'

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 96/01641

A. CLASSIFICATION OF SUBJECT MATTER			
IPC 6 C12N15/56 C12N9/28 C12N1/21 C12N15/70			
According to International Patent Classification (IPC) or to both national classification and IPC			
B. FIELDS SEARCHED			
Minimum documentation searched (classification system followed by classification symbols)			
IPC 6 C12N			
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched			
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)			
C. DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	
X	WO,A,94 26881 (KAO CORP ;ARA KATSUTOSHI (JP); SAEKI KATSUHISA (JP); IGARASHI KAZU) 24 November 1994 cited in the application see the whole document & EP,A,0 670 367 (KAO CORPORATION) ---	1-13	
X	BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS, vol. 151, no. 1, 29 February 1988, pages 25-31, XP000605386 TSUKAMOTO A. ET AL.: "Nucleotide sequence of the maltohexaose-producing amylase gene from alkalophilic Bacillus sp. #707 and structural similarity to liquefying type alpha-amylases." see the whole document ---	1,3-11	
A	---	2,12,13	
-/-			
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.		<input checked="" type="checkbox"/> Patent family members are listed in annex.	
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed			
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search	Date of mailing of the international search report		
6 November 1996	15. 11. 96		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016		Authorized officer Mandl, B	

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP 96/01641

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP,A,0 410 498 (GIST BROCADES NV ;PLANT GENETIC SYSTEMS NV (BE)) 30 January 1991 see the whole document ---	2,12,13
A	EP,A,0 410 498 (GIST BROCADES NV ;PLANT GENETIC SYSTEMS NV (BE)) 30 January 1991 see the whole document ---	3
P,X	WO,A,95 26397 (NOVONORDISK AS ;OUTTRUP HELLE (DK); BISGAARD FRANTZEN HENRIK (DK);) 5 October 1995 see the whole document -----	1,3-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/JP 96/01641

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		WO-A-	9100353	10-01-91
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